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(54) Method of making steering racks

(57) A method of making racks for rack and pinion steering gears for ground vehicles in which a rack blank is first shaped by machining, forging or other means having teeth which have a form corresponding approximately to the form desired in the finished rack the form of each tooth in the blank corresponds to the finished shape but is generally of greater radius; the total height of the tooth being greater than that of the finished shape and the volume of each tooth is substantially the same as the finished tooth. The teeth are then converted to the finished form by cold forming or coining in a die having a shape which is the exact counterpart of the finished shape.

The drawing(s) originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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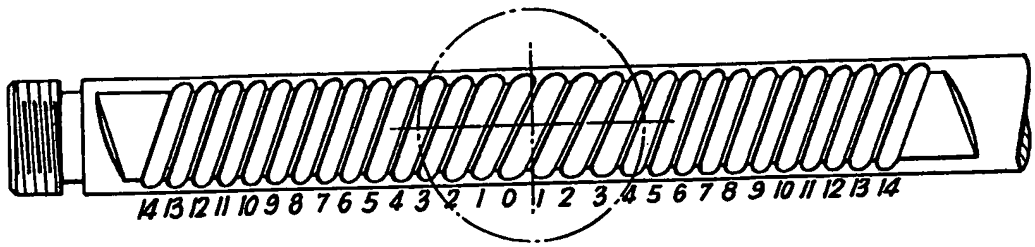


Fig.1.

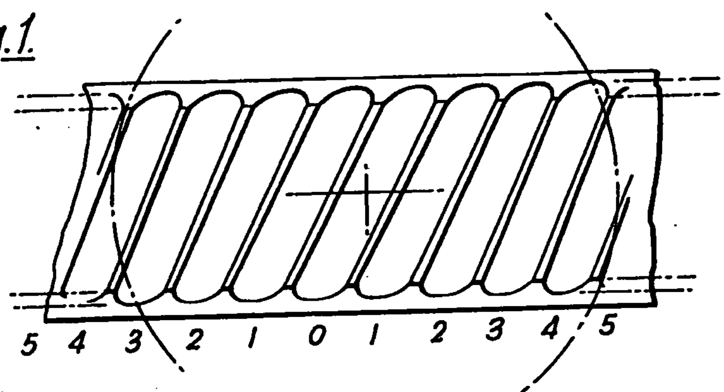


Fig.1A.

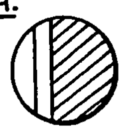


Fig.1B.

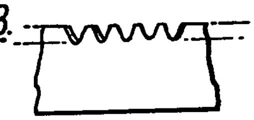


Fig.4.

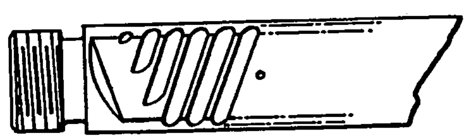


Fig.5.

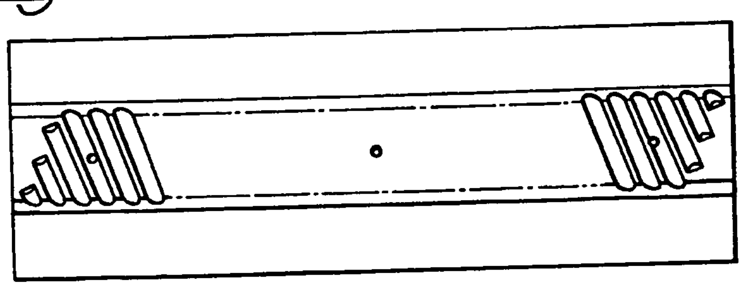


Fig. 2.

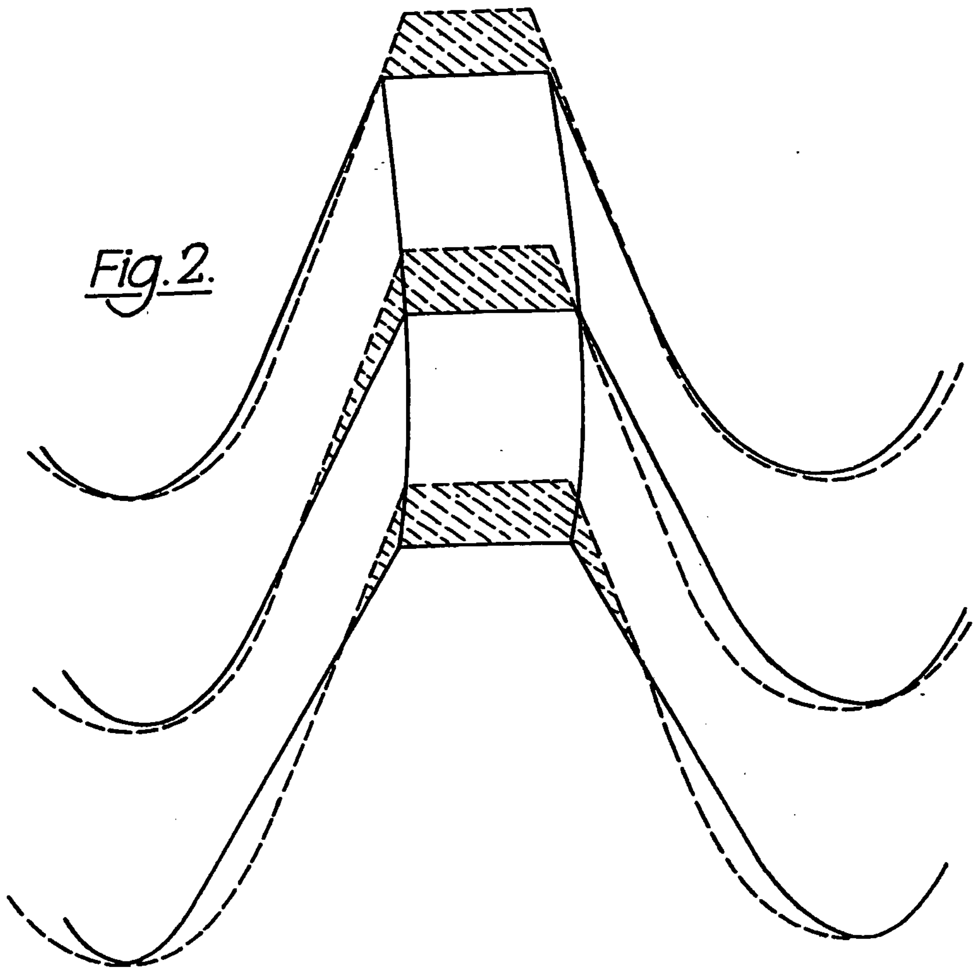
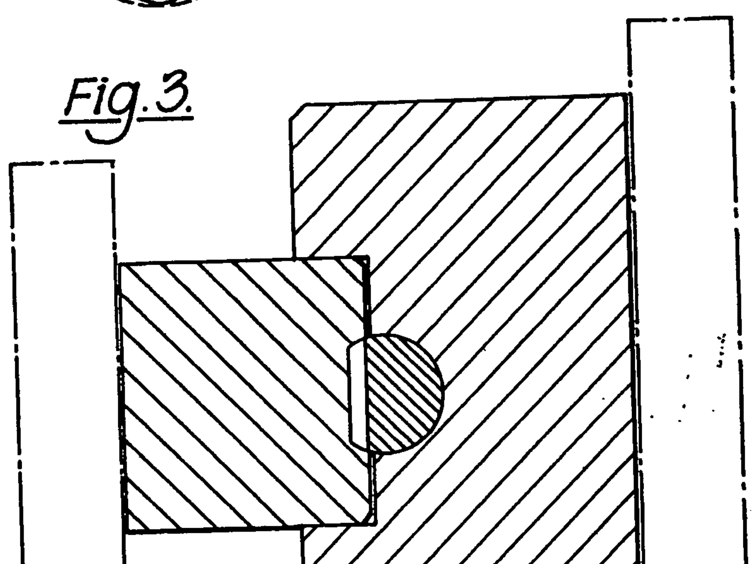


Fig. 3.



SPECIFICATION

Method of making steering racks

This invention relates to a method of making racks for rack and pinion steering gears for ground vehicles and is particularly, although not exclusively, applicable to the type of rack which provides a variable steering ratio, that is one in which a rack moves at a variable rate upon rotation at a constant rate of the steering wheel.

Such variability may be advantageous in a power steering gear to allow the use of a high steering ratio on center where speeds may be high and a substantially lower steering ratio away from center where speeds will generally be much lower, for example, as shown in Australian Patent 241798.

Alternatively in a manual steering gear, a variable ratio may be desired having an increase in steering ratio each side of center in order to reduce the steering efforts towards the lock where, conventionally, the steering efforts tend to be excessive.

Examples of such variable ratio gears appear in U.S. Patent 3,267,763 (Merit) and U.S. Patent Re 28740 (Bishop).

The steering racks used in these several types of variable ratio steering gears employ teeth which differ from standard teeth in several respects and which may vary in shape from tooth to tooth along the length of the rack. In the last named of the three above patents the teeth may in fact vary in shape along the length of any one tooth of the rack. Such teeth may be very difficult to form to a high degree of accuracy by any known manufacturing method.

It should be observed that high accuracy is essential if the rack teeth are to sustain the great loads to which such steering gears are subject and if a smooth tooth action is to be achieved so as to avoid undesirable jerkiness and to ensure the highest possible efficiency of operation.

It is also important that the teeth of such a steering rack have a very accurate finish in the root or fillet areas of the teeth and that the material in this area be free from longitudinal, (in relation to the length of the tooth,) defects or cutting marks.

A high degree of accuracy and finish is important not only in the case of variable ratio racks but also in the case of standard steering racks of the simplest kind intended to mesh with a straight cut pinion so that the method to be described is equally applicable to such standard racks.

In my co-pending Australian Patent Application No. 9216/77, British Patent No. 1,551,699, "Method of manufacturing variable ratio racks" I describe a method of making steering racks of the type described in the last named patent and in specific detail a method of rough machining such racks prior to exact finishing by a finishing process in which the racks are "deformed or otherwise shaped".

In the method of manufacture of steering racks which is the subject of the present invention this deforming is by cold forming under great pressure in a die which is the exact reverse facsimile of the desired shape of the finished rack.

Such dies can be made to a great order of accuracy and it follows that a rack finished by the method described will have imparted to it the high accuracy of the die, furthermore as the die is highly finished, the rack will also have tooth faces which are highly finished and free from longitudinal score marks which have been made by the roughing process and which are generally characteristic of other conventional methods of manufacturing racks. Such longitudinal marks are prone to start cracks in such highly loaded teeth which are subject to fatigue type stress reversals.

It may be thought that it would be possible to cold form such racks by taking a blank of steel and impressing teeth therein in a die, in the manner well known in the art of cold forming. However there are several reasons why such methods are not suitable in the case of steering racks. Firstly, in such cold forming, it is usual to fully contain the workpiece within the die so when the die fully closes the material is subject to very intense internal pressures and flows in the manner of a fluid. In order to so flow, it is accepted practice to use materials having high ductility, but such materials are not suitable for the manufacture of steering racks, for which purpose a material such as a carbon steel having .45% carbon is specifically used. Such material tends to work harden and tends to be poorly adapted to cold forming. Moreover the rack bar of a steering rack as generally used is of some considerable length for example 24" and the area to be formed into teeth occupies maybe 1/10th of the surface area of such a rack bar. The fully containing of such a large body, wherein such high pressures are to be developed would be very difficult to achieve in any known process. This will be more the case because the material commonly used has such reluctance to flow. It is for this reason that in the method described earlier the teeth are rough machined to an approximation of the finished shape, and in cold forming are merely set to the exact finished form required.

In one important further refinement of this process the preformed teeth are not merely a rough facsimile of the finished form, but rather a distorted form in which certain specific rules are observed. For example, it has been found that the rough formed tooth should have in the root or fillet areas a form closely approximating the finished shape but of larger radius; the total height of the tooth however should be substantially greater than the finished height and it should in most cases, but not all, have a narrower tip. There will be areas just above the root area in which the tooth in its rough machined form will be narrower than in its final form and it is into these areas that surplus metal from the tip will be displaced during the cold forming or coining operation. Furthermore the volume of the tooth as rough machined should be substantially the same as or slightly greater than that desired in the finished tooth. (Some variation may, however, be expected to occur due to densification of metal, or minor flow to other areas.) A very important aspect of this refinement is that the amount of flow of metal occurring is greatly reduced from the situation where metal may be required to flow up into the

cavity of the die in order to fill the difference between the final desired shape and the rough formed tooth. Essentially the process of forming the tooth thereby becomes one of successively squashing down layers of the tooth from the tip towards the root so that the material merely flows laterally in section until it touches the die cavity whereupon a layer of tooth below the first element worked also flows laterally to occupy its available space. By such a means the amount of flow taking place in any one element of the steel is greatly reduced and hence the material of low ductility can be worked satisfactorily. A further point is that, upon fully closing the die there is little tendency for the entire material of the core of the rack bar to be extruded lengthwise as would happen if the amount of fill varied along the length of the rack and hence surplus material had to be extruded lengthwise along a section of the bar, such extrusion lengthwise in the base stock of the rack might well sever certain teeth by shear or cause undesirable metallurgical properties in the root area of such teeth. A further important advantage of the process described in regard to the preformed shape is that there is little sliding of the metal being formed across the face of the die, and hence wear on the die is greatly reduced as compared with the accepted practices in cold forming. This aspect is most important where variable ratio racks are employed as the production of dies is a very expensive and elaborate process.

In a further refinement it should be noted that, in contrast to accepted practice in cold forming, the closing of the die would be limited according to the final closing pressure rather than to the shut height of the die. Thus when flow had occurred to substantially but not completely all of the root area of each tooth, closing of the die would cease.

The invention thus comprises a method of making racks for rack and pinion steering gears wherein a rack blank is first shaped to produce in it a plurality of rack teeth each tooth being shaped to form a corresponding approximately to the form desired in the finished rack, the form of the tooth in the root or fillet area corresponding fairly closely to the finished shape but being generally of a greater radius, the total height of the tooth being greater than that of the finished shape, and the volume of the tooth being substantially the same as the volume of the finished tooth, the teeth of the rack being converted to the finished form by cold forming or coining in a die having a shape which is the exact counterpart of the finished shape of the teeth.

The initial machining of the rack may be carried out in a variety of different ways for example by broaching, milling or a gear cutting operation.

In order that the nature of the invention may be better understood a preferred form thereof is hereinafter described by way of example with reference to the accompanying drawings in which:-

Figure 1 is a plan view of a rack for use in variable ratio rack and pinion steering gear,

Figure 1a is a section on V-V of Figure 1,

Figure 1b is a view in the direction of the arrow A,

Figure 2 is a view of a tooth of Figure 1 to an enlarged scale showing sections of the tooth at each end and in the middle both for the finished tooth and the rough machined tooth,

Figure 3 is a sectional view of the two halves of a rack coining die in the closed position,

Figure 4 is a view of a portion of a rack showing the shape of some of the teeth before the coining operation, and

Figure 5 is a view of the top half of the coining die showing the counterpart of the finished form of the rack teeth.

The rack illustrated in Figure 1 is an example of a rack for a variable ratio rack and pinion steering which can be manufactured by the method according to the present invention. The difficulties of making such a rack can be appreciated from the variations in the form of the rack teeth. It is however to be emphasized that the method can be used with advantage in the manufacture of racks of simple and straight forward design in which the teeth are all the same and are arranged at right angles to the axis of the rack.

During the process of manufacture, the teeth of the rack are first machined in rough form by broaching for example by the method described in the specification of the abovementioned Australian Patent Application. Other forms of machining such as milling or gear cutting may be adopted or the rack in rough form may be manufactured by a precise hot forging process or what is known as a warm forging process at about 1350°F. The object of the initial machining or forging operation is however to produce teeth corresponding fairly closely in shape to the finished form of the teeth for the rack but differing from them in a quite specific manner. This is illustrated in Figure 2 showing a view of a tooth of Figure 1 to a much enlarged scale and illustrating the sectional shape of the tooth at each end and at a point near the middle. In this figure the full lines represent the finished tooth shape, whereas the broken lines represent the rough machined shape of the tooth. From this figure it will be seen that at the root or fillet area on either side of the tooth the full lines and the broken lines coincide at one or more points. In areas above this on either side of the tooth the full line lies outside the broken line indicating that the tooth in its rough machined form is narrower here than in the finished form. In all three of the sections shown the tooth in its rough machined form is greater in height than the tooth in its final form and in the two nearer sections the tooth in its rough machined form is wider than in its finished form. The hatched areas of each section indicate metal available for displacement to fill the areas nearer the root of the teeth where the rough machined form is narrower than the finished form. In general the angles made between the flank of a tooth in its rough form will subtend an angle smaller than the angle subtended by those flanks of the tooth in its finished form.

The rack is finished by a cold forming or coining operation in which the surplus metal towards the tip of each tooth is displaced to fill the areas nearer the root. As can be seen from Figure 2 the volume of the tooth in its rough machine form is substantially

equal to the volume of the finished tooth and thus substantially all displacement of metal takes place within the volume of the tooth thus avoiding the disadvantages described above.

Figure 3 shows the coining die used for finishing the rack, the bottom half of the die serving to locate the rack bar and the top half serving to impart to the teeth of the rack the precise form desired.

Figure 4 shows some of the teeth of a rack in their rough machined form and Figure 5 shows the interior of the top half of the coining die in which a counterpart of the teeth of the rack in the finished form are incorporated. As is described above the interior surface of the top half of the coining die is very finely finished and during the coining operation imparts this high finish to the rack teeth thus serving to form them very precisely to the desired shape and also to do so without the formation of score marks. The coining operation itself is carried out in a conventional manner.

While the rack illustrated in the drawings is made from a bar of substantially circular cross-section the invention may advantageously be applied to racks of the cross-section illustrated in Figure 4 of Australian Patent 498666.

CLAIMS

1. A method of making racks for rack and pinion steering gears wherein a rack blank is first shaped to produce in it a plurality of rack teeth each tooth being shaped to a form corresponding approximately to the form desired in the finished rack, the form of the tooth in the root or fillet area corresponding fairly closely to the finished shape but being generally of a greater radius, the total height of the tooth being greater than that of the finished shape, and the volume of the tooth being substantially the same as the volume of the finished tooth, the teeth of the rack being converted to the finished form by cold forming or coining in a die having a shape which is the exact counterpart of the finished shape of the teeth.

2. A method of making racks as claimed in claim 1 wherein in the rack blank the angle subtended between the flanks of any one tooth is smaller than the angles subtended by those flanks in the finished rack.

3. A method as claimed in Claim 1 or Claim 2 wherein the rack blank is first shaped by machining.

4. A method of making racks as claimed in Claim 1 or Claim 2 wherein a rack blank is first shaped by hot forging.

5. A method of making racks as claimed in Claim 1 or Claim 2 wherein a rack blank is first shaped by warm forging.

6. A method of making racks for rack and pinion steering gears substantially as described with reference to and as illustrated in the accompanying drawings.

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